Canadian

Fusion

Fuels

Technology

Project

CFFTP

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Canadian Fusion Fuels Technology Project

CFFTP Project Summary

The Canadian Fusion Fuels Technology Project, [illegible] is a key element in Canada's National Fusion Program.

CFFTP is jointly funded by the Government of Canada [illegible] and Ontario Hydro.

CFFTP's mission is to extend Canada's fusion capabilities in [illegible] and applying fusion technologies. CFFTP's [illegible] programs are [illegible] areas:

- Fusion fuel cycle research and development
- Site, reactor system design and engineering, and safety analysis
- Safety and environmental aspects of fusion

In Canada, CFFTP manages and supports programs in research and development, engineering design, and transfer of technology to industry. Outside Canada, CFFTP has worksite partnerships with a number of fusion projects in Europe, the United States, and in Japan.

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Canadian Fusion Fuels Technology Project

2700 Lakeshore Road West
Mississauga, Ontario
Canada L5J 1K3
Tel: (416) 823-0200
Fax: (416) 823-8020

French Language Service:
(416) 592-2220
CFFTP Program Manager:
Donald P. Dautovich

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Message from The Honourable Jake Epp

Minister, Energy, Mines & Resources Canada

Canada's commitment to fusion research and development is solid and suited to our country's particular needs. It reflects our policy of diversifying our resources so as to maintain access to the energy supplies required to achieve our long-term economic, societal and environmental goals. As part of Canada's wide-ranging program of Energy Research and Development (PERD), the federal government, in concert with industry and the provinces, supports a national fusion program, of which the Canadian Fusion Fuels Technology Project (CFFTP) is a cornerstone.

A key element of the Canadian program is participation in international fusion activities. This provides access to leading edge international knowledge while fostering the development of scientific and industrial expertise at home.

Canada's contribution to the advancement of fusion science and technology is internationally recognized and appreciated, and CFFTP has been essential to that contribution in such key areas as fusion fuels and fusion engineering technologies.

CFFTP has also worked closely in partnership with Canadian industry, paving the way for international contracts for fusion-related products and services. CFFTP's research and its access to international research also shows promise for important technology spinoffs in non-fusion areas which Canadian industry can exploit.

I am pleased to note that CFFTP's unique approach to R&D cooperation and technology transfer has helped to position Canadian industry to take full advantage of commercialized fusion, while bringing the whole country nearer to the use of a clean and powerful new source of energy.

Jake Epp

Message from The Honourable Allan Pilkey

Ontario Minister of Industry, Trade & Technology

Prosperity through cost effective energy development will be of most value if it is achieved through harmony with the environment. Fusion power is one long-term energy option that has the potential to assist this goal.

Through scientific and technical co-operation, many developed countries around the world are contributing to fusion research and technology. By pooling their knowledge, expertise, and funding, they are improving the chances of realizing an energy option that requires international collaboration.

Through the work of the Canadian Fusion Fuels Technology Project (CFFTP), Ontario industry can participate in fusion research and enhance its competitive position by developing new and improved products and services. Overlaps between fusion and other high technology industries offer exciting prospects for technological R&D.

Equally important, universities, scientists, and students have access to a growing body of knowledge that allows them to further develop Ontario's technical skills and capabilities.

No country can afford to ignore the promise of an environmentally-stable and reliable energy option. My Ministry continues to support the efforts of CFFTP and its commitment to world fusion development.

Allan C. Pilkey

Message from Don Dautovich

Program Manager, CFFTP

This year's Annual Report of the Canadian Fusion Fuels Technology Project (CFFTP) highlights the value of fusion R & D. It describes efforts which are international in scope, and significant in depth.

The Annual Report also underlines the strong commitment to fusion demonstrated by CFFTP's associates in industry, universities, and the scientific community.

By working in partnership with these groups, CFFTP is pursuing strategies to transfer technological gains to the private sector, develop a unique base of Canadian scientific capability, and encourage young people to enter an advanced field of research and development.

The Business of Fusion

World fusion is a dynamic and flourishing business in its own right. Close to $2 billion is spent annually on fusion research and development.

While most of this funding comes from countries with the largest fusion programs–the European Community, the United States, Japan, and the USSR–Canada's contribution, although modest in comparison, represents a sound investment.

Canadian fusion efforts have a total value of about $25 million a year–including government funding, industry joint funding, and revenues gained from exporting fusion technology. With this funding, Canada is securing entry and international participation in an advanced high technology field at a fraction of the development cost.

Ten Years of Contribution

The Canadian Fusion Fuels Technology Project is now entering its tenth year of operations. It was established in 1982 as part of Canada's National Fusion Program. Together with its sister project, the Centre canadien de fusion magnétique (CCFM) near Montreal, CFFTP is charged with extending Canadian capabilities in fusion development.

In the short term, CFFTP's efforts have been directed toward providing universities and industries with the opportunity to expand their knowledge and capability in fusion R & D. Mostly, this has been done through involvement in CFFTP's scientific and technical collaboration on major fusion projects abroad.

In the longer term, these efforts will reap broader rewards for Canada. If fusion is eventually realized as a viable energy option, Canada should have the means to establish a domestic infrastructure, as well as the proficiency to supply major components of a fusion energy system.

CFFTP Funding

CFFTP funding is provided by three basic sources:

- base funding, under multi-year agreements, from the three CFFTP founding partners–the Federal Government, the Ontario Government, and Ontario Hydro;
- client funds from revenues received from fusion projects in the U.S. and Europe for services and manufactured hardware; and
- subcontractor funds in the form of in-kind contribution from subcontractors on development contracts awarded by CFFTP.

Source of Funds 1987/88–1990/91

- Provincial (13%)
- Federal (23%)
- Ontario Hydro (20%)
- Subcont. In-Kind (11%)
- Client Funding (33%)

Contributions by source for 1987–1991 totalled $44.4 million.

More than 75 per cent of these funds are used to carry out research, engineering, and manufacturing activities through subcontracts to affiliated research centres, universities, and industry. The balance is used by CFFTP in managing the program, providing technical direction and linkage to the international community.

Delivering the Benefits

In helping industry to export fusion goods and services to world programs, CFFTP is enhancing Canada's competitive position.

For example, the Chalk River Laboratories, operated by Atomic Energy of Canada Limited (AECL), notes that its work on fusion fuel and tritium technology has allowed AECL to develop broad expertise that is closely integrated at one site–an uncommon position in the world.

Other private sector companies–like Spar Aerospace, E.S. Fox, and E.G. & G. Labserco Ltd.– view their fusion work as providing significant value. These companies have listed employment creation, the development of unique products, and spinoffs from current research as some of the benefits.

As mentioned earlier, CFFTP is also helping to develop and build an important base of fusion knowledge in Canadian universities. McMaster University has praised fusion research for its ability to strengthen the technological knowledge of young scientists.

CFFTP is also delivering benefits to Ontario's electricity customers through its relationship with one of its founding partners, Ontario Hydro.

While some of these benefits will involve a long term payoff–access to fusion as a future energy option–CFFTP technology also has relevance to Hydro facilities and operations today.

For example, by working with a cross-section of Canadian suppliers–particularly in the areas of tritium and remote handling equipment, and tritium monitors–CFFTP is helping to maintain an industrial capability through a strong resource base of domestic companies. During the past two years, the value of contracts received by industry averaged more than $4 million annually.

As well, research being done on the application of plasma furnace technology to fusion wastes has potential to further reduce radioactive effluents at Hydro nuclear facilities, and demonstrate Hydro's positive commitment to environmental protection.

The Challenge Ahead

Fusion research will continue to pose challenges to the international scientific community. Yet for all the hurdles to be overcome, substantial progress continues to be made.

The search for an energy form that is safe, reliable, environmentally sound, economically competitive, and can be shared by nations around the world is no minor quest. It is a major goal worth pursuing that merits Canada's commitment and support.

Don Dautovich
Program Manager

Fusion as an Energy Source

Fusion power is not unlike the power of the sun, where a series of fusion reactions release energy in the form of sunlight.

Fusion as an Energy Source

For about 40 years now, scientists have been exploring the mysteries and the promise of fusion power.

The first research into fusion in the early 1950s was carried out independently—in the United Kingdom, the United States, and the Soviet Union. As the extent of the fusion challenge became known, industrialized countries began to collaborate on fusion research in the late fifties and early sixties.

That collaboration—in which Canada plays an important role—continues today and now includes Japan, the European Community, as well as the U.S.A., the Soviet Union, and many developing countries.

Fusion—The Power of the Universe

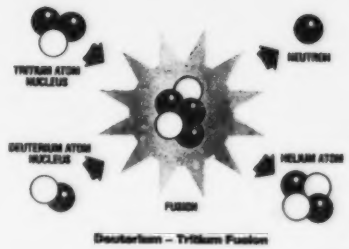
Fusion is the energy source of the sun and the stars—and the energy process of the universe. The sun acts as a giant fusion reactor that continuously converts hydrogen to helium through a series of fusion reactions. These reactions release the resulting energy in the form of sunlight.

Fusion can occur in the sun because tremendous gravitational forces squeeze and heat its gases to about 15 million degrees celsius. The pressure and temperature working together, compress the atoms and allow the nuclei to fuse. Since gravitational forces on Earth are too weak to produce fusion reactions, humankind must create the necessary conditions.

Like fission—the process which occurs in a nuclear power reactor—fusion exploits the conversion between mass and energy that occurs during nuclear reactions. Yet fusion is the opposite of fiss.on.

In the fission process, energy is produced by splitting very large atoms into smaller ones; in fusion, energy is released when very small atoms are united to form larger ones.

The easiest fusion reaction to achieve is that between the two isotopes of hydrogen—deuterium and tritium—the



Deuterium-Tritium Fusion Reaction. At temperatures over 100 million degrees, nuclei of deuterium and tritium atoms can be made to breach natural repulsion barriers and fuse together.

products of which are helium and neutrons (which carry the bulk of the energy released). If the kinetic energy of the neutrons can be transformed into heat, and this heat transferred via a heat exchanger to raise steam to power a generating plant, the end product will be electricity.

From Theory to Reality

Despite scientists' knowledge of the fusion process itself, no one has yet been able to make fusion power work. That's because simulating the conditions of the sun is technically extremely demanding.

In order for the atomic nuclei to fuse they must overcome very strong repulsive forces; at low temperatures, they simply collide with each other and rebound.

Therefore, the atoms must be heated to very high temperatures—in the order of 100 million degrees celsius. (As a point of comparison, most heat-resistant materials used in industry melt below 4,000 degrees celsius.) In such conditions, the nucleus and electrons separate and exist in the form of an ionized gas known as plasma.

This objective—to fuse atoms—is only the first step. The fusion process must also be tamed in order to obtain a worthwhile net energy output. Fusion scientists have defined two successive requirements which must be met for fusion to be considered a feasible energy producer.

PHOTO: CANADIAN FUSION FUELS TECHNOLOGY PROJECT

The first, known as break-even, marks the point at which the energy released by fusion reactions matches the energy used to heat the plasma. The second, known as ignition, is the point at which the fusion process becomes self-sustaining, and more energy is released than was initially put into the plasma.

Despite the theoretical quality of these goals, tangible progress is being made.

Progress Continues

Major facilities in the United States, the Soviet Union, Europe, and Japan continue to work toward advances in the understanding of compression, heating, and confinement of plasmas.

These facilities have improved the plasma parameters by more than five orders of magnitude in the past decade. They have also created a knowledge base which will enable the design and construction of a fusion reactor to proceed beyond the experimental stage to next step fusion machines, such as the International Thermonuclear Experimental Reactor (ITER).

Other milestones have also been attained. For example, temperatures of more than 400 million degrees centigrade have been reached at the Princeton fusion facility. Operations at the Joint European Torus (JET) facility, in England, have produced combined parameters equivalent to 80 per cent of that required for break-even, and a factor of 20 away from ignition.

It is expected that scientific break-even will be established with the introduction of tritium fuel over the next two to three years. Ignition is expected to take place within a further 10 years. The actual operation of a fusion power demonstration plant is considered possible by the year 2025.

At first glance, the immense scientific effort and financial investment required to develop fusion may appear questionable. After all, a fusion reactor would generally perform the same job as a coal-fired boiler or fission reactor in today's generating stations.

Yet, if the potential of fusion is ultimately realized, there are substantial environmental and safety benefits.

Environmental and Safety Advantages

Unlike fossil fuels, fusion does not release gases into the atmosphere that contribute to air pollution, acid rain, and the greenhouse effect. Fusion reactors will also be powered by fuels which are abundant.

The first commercial facilities will be fuelled by deuterium and lithium—to breed tritium. Both materials are in abundance on the planet, in the oceans or in ore bodies (lithium). Conceptual fusion power plant designs have been established and indicate safe operating characteristics. This is because the small amount of high-temperature gas—plasma—which makes up the fusion fuel has insufficient heat content to cause major damage to the plant.

In addition, fusion reactions are difficult to sustain, so any plant malfunction would result in a shutdown.

Safety can be assured through designs that are inherently safe through the minimization and stringent confinement of radioactivity in a fusion power plant. The radioactive elements of an initial commercial fusion reactor—such as tritium—represent a modest biological hazard, and are readily contained.

Material activation—which also will occur due to structural materials absorbing neutrons created by the fusion process—can be reduced through the use of appropriate "low activation" materials.

PHOTO: ONTARIO HYDRO RESEARCH DIVISION

The potential of fusion power holds significant environmental advantages, as it does not contribute to air pollution, acid rain, and the greenhouse effect.

With carefully selected materials, much of the radioactivity produced by a fusion machine will qualify as low-to-medium level waste, and will require only modest storage times before decaying to safe levels and possible recycle.

A Worthwhile Challenge

No one would deny that the technological challenges presented by fusion development are great.

Demonstrating that fusion is feasible requires not only the development of systems to contain and heat the plasma, but also systems to make and handle tritium, to inject fuel, to keep the plasma free of impurities, to remove wastes, to convert the energy into useable heat, and to enable essential maintenance, replacement, and repairs.

Yet, while the research investment is substantial, so are the rewards.

Fusion involves the pursuit of a future energy source that is both available and acceptable. Fusion research is worthwhile because of the development it has stimulated. Such development is not confined to physics and technology alone, but includes the training of young scientists and researchers, unintended spinoff technologies for non-fusion applications, and industrial support through the production of goods and services.

CFFTP's role in co-ordinating and delivering these benefits is explored in the following pages.

Fusion Technology

Canada's design, development, and operation of CANDU nuclear plants has resulted in CFFTP having considerable experience and knowledge of tritium's relationship to the environment and public safety. The Darlington Nuclear Generating Station, owned by Ontario Hydro, has the largest tritium removal facility in the world.

The technical skill and capability Canada brings to world fusion development arises from its many years of experience in both the nuclear and aerospace industries.

It is this experience that the Canadian Fusion Fuels Technology Project (CFFTP) has been able to leverage in order to pursue research, and to secure industrial contracts, in its key areas of expertise—tritium technology, nuclear safety and design, and remote handling.

Leveraging Canadian Capabilities

The CANDU nuclear system, developed and employed in Canada, produces small amounts of tritium as a by-product—due to its use of heavy water as a coolant and moderator.

For Canada the development and operation of CANDU plants—and because of the presence of tritium—focused considerable attention on tritium containment, operational and worker safety, and the monitoring and understanding of tritium's relation to the environment and public safety.

This experience is directly relevant to the safety-related skills and technologies necessary for application to existing and future fusion technologies.

In addition to this experience, the recently commissioned Darlington Tritium Removal Facility—owned and operated by Ontario Hydro at its Darlington Nuclear Generating Station—will also offer important information for fusion development.

This facility—the largest of its kind in the world—has been built to enhance nuclear worker safety by removing tritium (which builds up over time) from the heavy water used in CANDU plants. Canadian R&D in tritium extraction technology, and experience gained in the design and operation of the Darlington tritium removal facility will assist in the design of tritium systems for future fusion facilities.

Through contracts with Ontario Hydro, CFFTP will also be able to offer world fusion programs, on behalf of Canada, a reliable supply of tritium in the amount that will be required in the near future as a fusion fuel.

PHOTO: ONTARIO HYDRO

A key area of proficiency involves remote handling. Since CANDU reactors are designed to operate with on-line fuelling (no shutdown is needed), the Canadian nuclear program has developed reliable robotic systems for this purpose, as well as for inspection, maintenance, and repair of nuclear systems.

This experience is further enhanced by research in the aerospace sector. Canada has contributed to the U.S. space shuttle program by developing a remote manipulator, and is currently anticipating development of space repair systems for the U.S. space station project.

PHOTO: SPAR AEROSPACE

Canada's impressive track record in robotics—both in the aerospace industry and the nuclear industry—has boosted CFFTP's international profile in fusion projects. Shown here is the Canada Space Arm, designed and developed by SPAR Aerospace.

This valuable track record in robotics has given CFFTP, working on behalf of Canada, an international profile in world fusion projects.

A Strategy to Succeed

CFFTP's R&D program has been strongly oriented to the needs of selected technology areas in major fusion projects. In applying its unique skills and experience to niche technology applications, CFFTP is helping to secure maximum value for Canada's fusion investment.

CFFTP's Fusion Systems and Engineering area focuses on the tritium breeding blanket, first wall protective materials and fuel processing systems.

Blanket studies include the development and in-reactor testing of lithium ceramic breeding materials and designs that would "breed" tritium from lithium within a blanket surrounding the reactor chamber.

CFFTP's effort focuses on developing a sphere-pac solid ceramic breeder blanket, using microspheres of lithium zirconate as the breeder material. The Advanced Ceramics Group at the Chalk River Laboratories has developed industrial methods of producing ceramic grade powders and of forming 1–3 mm diameter ceramic spheres. Industrial Ceramics of Mississauga was involved in the production of ceramic powders.

Nuclear qualification tests, through in-reactor irradiation experiments, are being conducted to evaluate tritium production and release processes in blanket materials. Non-nuclear qualification tests, such as thermal conductivity and mechanical strength, have also been started.

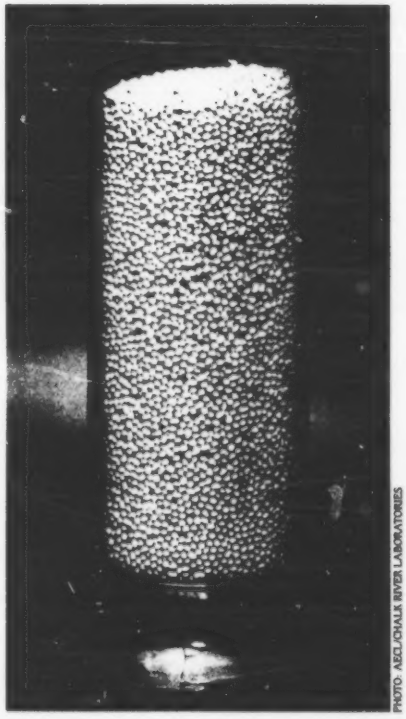


PHOTO: AECL/CHALK RIVER LABORATORIES

Lithium zirconate spheres fabricated at Chalk River Laboratories and supplied for BEATRIX-II, Phase 2.

The first wall refers to the material that forms the inside of the reactor chamber that contains the hot plasma. Such material will have to withstand not only the high heat, but also erosion by the plasma as well as the intense neutron flux.

First wall research is conducted at the University of Toronto Institute for Aerospace Studies (UTIAS). It focuses on hydrogen isotope interactions with the first wall, as well as the development and testing of improved first wall protective materials to meet the very demanding performance requirements of next-step fusion machines.

Through CFFTP support, UTIAS has recently acquired a unique dual-beam accelerator. This permits studies of synergistic effects resulting from the combined impact by two energetic ion species such as those found in the fusion

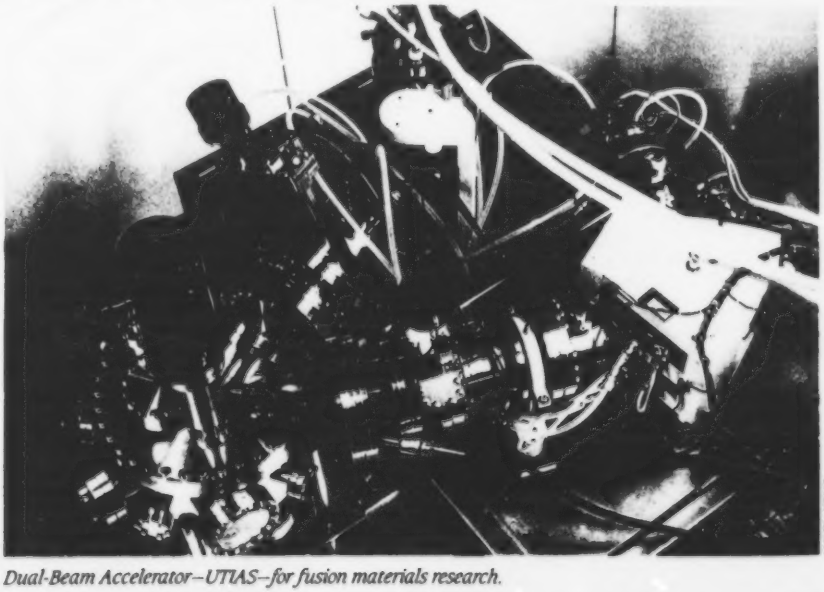


PHOTO: UTIAS

Dual-Beam Accelerator—UTIAS—for fusion materials research.

plasma. CFFTP is also working with industry, such as ALCAN and Ceramics Kingston, to develop specially doped carbon fibre composite materials with improved resistance to plasma erosion.

Fuel processing systems development includes fuel storage and handling, plasma exhaust purification, hydrogen isotope separation technologies, tritium extraction from blanket, containment atmosphere tritium removal, and tritium extraction from water.

CFFTP's approach is to develop processing systems with improved safety (especially low tritium inventory), reduced costs, and improved reliability. Suitably scaled prototype construction and testing, including tritium testing, is an increasingly important part of the program.

Key systems being developed include a very low inventory cryogenic distillation based hydrogen isotope separation system, improved gas chromatographic based hydrogen isotope separation system, blanket tritium extraction by pressure swing adsorption, and plasma exhaust purification by the HITEX process (High Temperature Isotope Exchange).

Under contract to SCK/CEN at Mol, Belgium, CFFTP is conducting testing at the Chalk River Laboratories of a special low inventory electrolysis cell for use in plasma exhaust purification. This provides valuable experience in the processing and handling of very high tritium concentration water.

Fuel processing system design is closely integrated with system development and testing. A powerful computer code, FLOSHEET, has been developed and successfully applied in the engineering design and optimization of fuel systems. The code was originally developed for the Darlington Tritium Removal Facility and has been validated through application at Darlington.

Fusion Systems and Engineering Highlights 1990–91

Breeder Material Fabrication	Industrial methods of producing ceramic grade powders ($LiAlO_2$ and Li_2ZrO_3), and of forming 1–3 mm diameter ceramic spheres have been developed. Li_2ZrO_3 spheres have been supplied to the BEATRIX-II in-reactor irradiation experiment, and to several research groups for thermal conductivity, gas permeability and physico-chemical measurements.
First-Wall Research	A unique dual-beam accelerator has been built and successfully commissioned. It consists of two independently controlled low-energy, mass-analyzed ion accelerators. It permits studies of synergistic effects resulting from the combined impact by two energetic ion species such as C^+ and H^+, or C^+ and O^+. Chemical erosion tests over a temperature range of 500K to 1000K on boron and silicon doped carbon/carbon composite samples fabricated by ALCAN showed up to 3 times lower erosion compared to the reference material without doping.
Plasma Exhaust Impurity Processing	The HITEX (High Temperature Isotopic Exchange) conceptual design for plasma impurity processing was developed. Tritium is exchanged out of impurities such as tritiated methane, ammonia and water by swamping with H_2 and isotopically equilibrating the mixture in a high temperature reactor. The reactor consists of a horizontal tube with an axial coiled Pt metal hot-wire operated at a temperature of 1173K. The walls of the reactor are cooled to near room temperature to minimize permeation. An experimental loop has been built to test the concept, initially using H_2 and deuterated impurities.
Low Tritium Inventory Cryogenic Distillation	A special low tritium inventory cryogenic distillation column has been built and tested for hydrogen isotope separation. Results showed that, compared to conventional designs, the new system could reduce tritium inventory by a factor of 5 to 7.
Blanket Tritium Extraction by PSA	A conceptual design based on pressure swing adsorption (PSA) has been developed for recovering hydrogen isotopes from the ITER solid breeder helium purge stream. The PSA process is advantageous over the temperature swing adsorption (TSA) ITER reference design because it allows much faster cycling and therefore has significantly lower tritium inventory. For example, a PSA cycle of 10 minutes has 48 times less tritium inventory than an 8 hour TSA cycle. Adsorption isotherm data for H_2 down to 1 torr have been experimentally obtained. Experiments are underway to test the concept.
Compact Toroid Fuelling	A collaborative project is underway to demonstrate centre-fuelling by the injection of compact toroids (CT). The project is coordinated by CFFTP and involves the University of California at Davis, the University of Saskatchewan, and the Tokamak de Varennes. The CT fueller is based on the UC-Davis design. It will be built at the University of Saskatchewan and functionally tested at the STOR-M tokamak there. Demonstration of disruption-free CT fuelling to plasma centre will be done at the Tokamak de Varennes.

Frank Londry (foreground) and Ken Fowler, Trent University, are preparing the apparatus for conducting thermal conductivity measurements of a packed breeder ceramic sphere bed.

Another area of CFFTP's work program–Facilities Engineering & Safety Services (FESS)–offers expertise in significant tritium safety technologies and systems, as well as remote handling for fusion and related applications.

This work includes development of tritium monitors and dosimeters, air detritiation systems for atmospheric clean-up, development of barriers for tritium permeation in reactor structures, and research which increases the knowledge of tritium behaviour in the human body and in the environment.

In addition, FESS also offers important training and information exchanges on tritium and fusion engineering to CFFTP associates and contractors, and Canada's scientific community.

Two successful workshops held in the last year included a Fusion Basics Workshop in November 1990, and a Tritium Safety Workshop held during March 1991. As well as sharing updated information and providing valuable training, such workshops help to further develop a skills and knowledge base in Canada for fusion research.

Strategies for the Future

CFFTP has developed a range of technology strategies which will strengthen Canada and Ontario's roles in fusion R & D.

Tritium technology, advanced materials, safety, robotics, and nuclear design will all continue to be core work programs, subject to periodic review for viability and relevance.

In particular, key areas noted as having potential for future CFFTP marketing and expertise are: detritiation of cooling and waste water from fusion reactors; reporting and data bases related to tritium safety; licensing and regulatory matters; remote handling; and safety, testing, and licensing data for large shipping containers.

Other technology strategies which have been identified call for CFFTP to:

- Maintain a balanced set of technology links with major fusion countries; this will involve continuing the strong links with European and American programs, strengthening links with Japan, and establishing links with the Soviet Union.
- Provide technology, hardware, and staff support to the tritium operations of the Joint European Torus (JET) in England, the Tokamak Fusion Test Reactor (TFTR) at Princeton University, to international tritium labs, to the design of the Next European Torus (NET) in Germany, and to the design of the Burning Plasma Experiment (BPX) in the United States.
- Identify the needs and establish programs to support the decommissioning and waste management for fusion facilities operating with tritium.
- Establish links with programs in inertial confinement and alternate magnetic confinement fusion concepts, with a view to monitoring progress, offering services, and developing resource capabilities.
- Contribute to the International Thermonuclear Experimental Reactor (ITER). This reactor concept, now nearing the engineering design stage, is viewed as the most promising next step reactor, which would test engineering feasibility of fusion, and eventually, commercial demonstration.
- Assist the transfer of fusion technology to other sectors for non-fusion applications.

Facilities Engineering and Safety Services Highlights 1990–91

Safety Criteria	Tritium fuel is a key radiation safety consideration in current experimental reactors and in future commercial plants. Canada's experience with tritium has given it a leadership position in tritium safety, and therefore, fusion reactor safety is a logical focal point for CFFTP. Fusion reactor safety is achieved, at the design stage, by the application to stringent safety criteria, design standards, the use of radiation compatible materials, and to the greatest extent possible, by the application of proven technologies and equipment. The demonstration of safety, at the design stage, is provided by analysis and testing. CFFTP has been active in this area, providing safety support services to international fusion projects.
Analysis Code Development	Sophisticated computer codes, that simulate the response of the plant to equipment failures and accidents, are used to predict radiological consequences. The results of these analyses are used by designers to optimize their designs, and by safety experts to determine the overall level of safety achieved.
Radioactivity Confinement	The confinement of tritium fusion fuel to limited areas of a fusion energy plant involves the use of high integrity, building and equipment seals, specialized ventilation systems with isolation provisions, and a knowledge of tritium behaviour within buildings. Studies have been funded at the Chalk River Laboratories of Atomic Energy of Canada Limited on the absorption and desorption of tritium on building surfaces, and on special air clean-up systems. This experimental program provides the necessary information to design confinement isolation systems to safely manage tritium fuel under both normal and abnormal operating conditions.
Waste Processing	In order to reuse and recycle radioactive and expensive tritium, R&D is sponsored to allow the design of processes to recover tritium from solid and liquid waste streams, and from machine components. This includes a program to develop techniques for decontaminating tritiated surfaces.
Fusion Engineering Training	In support of human resource development, FESS sponsored Fusion Basics and Tritium Safety workshops. The workshops covered the fundamentals of fusion physics, tritium behaviour, and engineering considerations. This is essential knowledge for the design integration role which CFFTP and subcontractor staff play in a number of international projects.
Remote Handling	CFFTP and SPAR Aerospace Ltd. are partners with Commissariat a L'Energie Atomique (CEA) of France in providing the detailed design of a robotic system to perform maintenance tasks inside the Next European Torus fusion device.

Prototype of a tritium isotope separation system purchased through CFFTP by Kernforschungszentrum Karlsruhe in Germany. It was developed by Ontario Hydro Research Division.

Technology Applications, Transfers and Spinoffs

The Canadian Fusion Fuels Technology Project (CFFTP) continues to play a significant role in developing industrial capability in fusion technology, and supporting Canadian competitiveness abroad.

It pursues these goals using three key approaches:

- Transferring technology developed in the laboratory to qualified industries;
- Creating business opportunities for industry through marketing of developed products, services, and custom engineering systems to international fusion projects; and
- Identifying and responding to opportunities to spin off fusion technology to non-fusion applications.

Since much of Canada's fusion investment is long term, it is important for CFFTP to maximize short term benefits by providing technological and economic value to industry. It does this by adding to industry's knowledge base, and leveraging funds for industry through its role as a unique marketing agency for fusion hardware and services.

Distribution of Funds by Sector 1987/88–1990/91

- Ontario Hydro (20%)
- Industry (31%)
- University (6%)
- AECL (21%)
- Reserve (1%)
- CFFTP (21%)

Total funds distributed for 1987–1991 amounted to $44.0 million.

Over the years, CFFTP has been successful in assisting industry to win engineering, research, and manufacturing contracts from both fusion and non-fusion clients overseas. Total annual value of contracts awarded to industry grew to more than $4 million by 1990, compared to less than $1 million in the mid-80's.

Some important fusion technology applications, as well as potential spinoffs, are outlined in the following sections.

Technology Applications

Gas Chromatograph Isotope Separation System

CFFTP continues to work with several Canadian companies on designing and manufacturing a hydrogen isotope separation system based on gas chromatograph technology for use at the tritrium laboratory at KfK in Germany.

An Ontario company—E.G. & G. Labserco Ltd. of Oakville—is administering the offshore subcontracts. In its role as the main design and supply contractor, E.G. & G. Labserco are designing the control system and will assemble and test the complete system in Canada prior to shipment.

Major components of the system are being supplied to E.G. & G. Labserco. These include five uranium beds for tritium storage designed and constructed by Atomic Energy of Canada Limited's (AECL) Sheridan Park Engineering Laboratories; a zirconium/iron scavenger bed manufactured by E.S. Fox Limited of Niagara Falls; and cryogenic vessels and the mainframe assembly being constructed in Germany by two local companies. Ontario Hydro played a design and development support role in the project. This system resulted from a development program originally started in 1983 by CFFTP and carried out by Ontario Hydro Research Division.

Analytical Gas Chromatograph

An analytical gas chromatography system has been designed and built for the Joint European Torus (JET) project in England. This system will analyze gas streams in the reactor's Active Gas Handling Systems (AGHS)—which, in turn, processes exhaust

PHOTO ORIT - ... RESEARCH DIVISION

gases from the JET torus and purifies and recycles tritium/deuterium fuel gases.

The gas chromatograph system will measure concentration of gases, including helium, oxygen, organics, and hydrogen isotopes, in a number of AGHS process streams. CFFTP's Canadian contractors on the project were E.G. & G. Labserco and AECL's Chalk River laboratories. The system was delivered to JET in February 1991 following extensive testing.

Tritium Fill Station

A tritium microballoon filling station was delivered to the University of Rochester in June 1990 following design, manufacturing, and testing in Canada. The station fills spherical plastic capsules with deuterium/tritium gas mixtures at high pressures. These spheres will be irradiated during inertial confinement fusion experiments on the OMEGA high power glass laser at the university.

CFFTP acted as the prime contractor of the tritium fill station. Wardrop Engineering of Mississauga designed the system, High Vacuum Systems Inc., also of Mississauga, fabricated and tested the system, and E.S. Fox built and supplied two uranium beds for tritium storage.

Once the University of Rochester completes supporting facilities, the station will be installed and commissioned.

Secondary Enclosure Clean-up System

CFFTP recently concluded an agreement with SAES Getters Inc/USA for the joint development and marketing of a system which will detritiate the inert atmosphere of "glove boxes". (Glove boxes are leaktight boxes, containing air or inert gases, which enclose radioactive equipment or samples. Rubber gloves which penetrate the box through its plexiglass sides allow technicians to manipulate the items in the box, while still being protected from hazardous substances. However, the atmosphere within the box does need clean up and pressure control due to the toxic materials.)

The final commercial units of the clean-up system will be based on a development and prototype demonstration program which is underway at Ontario Hydro's Research Division, under the joint responsibility of Ontario Hydro and CFFTP. The system depends upon a patented SAES alloy material doubly-contained in a getter bed built by E.S. Fox.

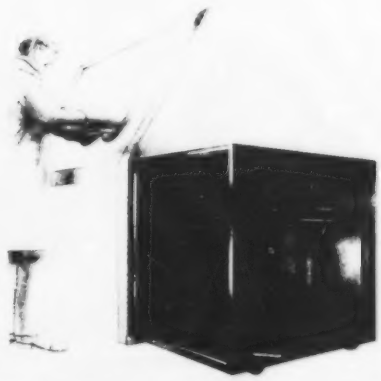


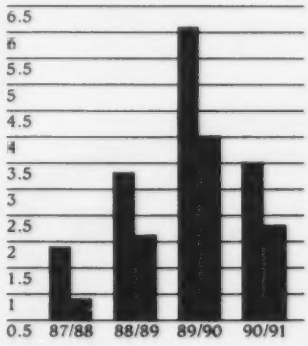
ILLUSTRATION: ETO GRAPHICS

Glovebox Cleanup System (Artist conception): SAES Getters is collaborating with CFFTP to develop and produce commercial cleanup systems for fusion research and for industrial applications which involve the handling of tritium.

Technology Spinoffs

By developing opportunities to apply fusion technologies to other sectors of the economy, CFFTP is providing multiple pay backs on Canada's fusion investment.

Exports of Technology Products by Industry Sector
1987–1991 ($M)



Industry sector accounts for 63% of total exports over the last four years.

Some fusion technologies offer opportunities for synergy with the alternative energy sector, the environmental sector, and aerospace industries. Companies in these

PHOTO: ONTARIO HYDRO RESEARCH DIVISION

From Left to Right: Michael McParlan, E.S. Fox Limited, Joe Lehman, CFFTP and Clive Morton, Ontario Hydro Research inspect a Zirconium-Iron Scavenger Bed during conditioning for a Gas Chromatographic Isotope Separation System for KfK in Germany.

sectors are also finding that their products and services may have application for fusion itself, leading to further opportunities to expand and diversify their markets.

In addition, the application of fusion technologies to other sectors allows these technologies to be tested, refined, and kept up to date. Some key fusion technologies with potential for other industries are as follows:

Advanced Gaseous Separation Systems

These systems, which have been developed for tritium purification or to separate tritium from various gas streams, can be adapted for oxygen or nitrogen production or for the purification of hydrogen.

Research laboratory ORTECH International has examined the technical and economic potential of one such technology, known as the Thermally Coupled Pressure Swing Absorption (TCPSA) cycle. Preliminary results indicate that it offers some technically attractive features, including the potential for energy conservation in medical oxygen and nitrogen production processes–both of which are electricity intensive.

Other potential applications for these systems involve alternative energy options, industrial use, and environmental protection. For example, the production, storage, purification and handling of hydrogen necessary for fuel cells–an environmentally-attractive energy option–is similar to that used in the handling of fusion fuels, such as deuterium and tritium. Gaseous separation also holds promise for exhaust gas clean-up in industrial processes and transportation, as well as CFC-free refrigeration.

High Temperature Processes

These processes are of interest to the fusion community for the conditioning of fusion wastes. They are also of interest to other scientific communities for conditioning of toxic and medical wastes. For example, materials such as discarded first wall tiles, Tokamak dust, and water purification system resins require appropriate conditioning for their safe handling and disposal.

Totally enclosed high temperature processes–such as plasma or induction heating–operating in a controlled environment offer technology development opportunities for the safe conditioning of other hazardous wastes.

The performance of plasma and induction furnaces is being investigated for conditioning of purification systems resins. Results from this investigation may be of interest to Canada's nuclear program for the processing of used resins.

Composites

Material development for use in hostile environments have application for both fusion and aerospace research.

Fusion first wall materials research deals with similar challenges to those posed by the space program. This is why the University of Toronto Institute for Aerospace Studies has taken a leading role in the study of fusion plasma-materials interactions.

An Ontario company, Ceramics Kingston, is manufacturing doped graphite first wall material to CFFTP specifications. This material will be tested by the Institute, for fusion applications and possible applications to the space program.

International Profile

Since 1982, as part of the National Fusion Program, the Canadian Fusion Fuels Technology Project, located in Mississauga, Ontario, has represented Canada—along with its sister project, the Centre canadien de fusion magnétique near Montreal—in world fusion research and development projects.

International Profile

The key challenges facing the Canadian Fusion Fuels Technology Project (CFFTP) in the years ahead are to continue to optimize funding, and maintain relevance to international fusion programs.

To date, CFFTP's acknowledged expertise, applied strategically to global projects, has helped secure Canada's profile and reputation in fusion R & D.

CFFTP has achieved international recognition as a world leading project in the field of tritium technology. Technology represented by CFFTP has been largely responsible for Canada's acceptance in activities related to the International Thermonuclear Experimental Reactor (ITER).

ITER–Consensus and Co-operation

ITER–an experimental project involving international collaboration on an unprecedented scale–is the most advanced fusion proposal for the next step device.

Representatives from Europe, Japan, the United States, and the Soviet Union are working jointly on this reactor project to further fusion knowledge. Canada is an active participant as a member of the European team.

The schedule for ITER calls for the participants to start detailed design for the reactor in 1992, and construction in 1997. First plasma is expected around 2005.

Research and development activities related to the International Thermonuclear Experimental Reactor (ITER) involve scientific collaboration among countries on an unprecedented scale. ITER is generally regarded as today's most advanced fusion project.

ITER would produce an ignited plasma–in other words, fusion power on its own would maintain the plasma temperature. This would provide an opportunity to identify plasma operating conditions that best optimize performance. In addition, ITER will demonstrate most major technologies for a fusion reactor, including large superconducting magnets, fuel cycle, maintenance technologies, diagnostics, and vacuum systems, among others.

International Staff Attachments

Peter Stangeby	Of UTIAS; attachment to Joint European Torus (JET); researching erosion of reactor limiters.
Spencer Pitcher	Formerly of UTIAS; part-time attachment to Princeton Plasma Physics Laboratory (PPPL); studying the plasma edge on the Tokamak Fusion Test Reactor (TFTR).
Paul Dinner	Of CFFTP; attachment to Next European Torus (NET), as Leader-Tritium Systems.
Dave Murdoch	Of Qualprotech; attachment to NET; tritium systems.
Bob Sissingh	Of CFFTP; attachment to TFTR as Head of Tritium Systems.
Otto Kveton	Of CFFTP; attachment to European Community International Thermonuclear Experimental Reactor (ITER) team (Tritium Systems Design).
Sandra Brereton	Of CFFTP; attachment to Lawrence Livermore National Laboratory, assisting in U.S. Fusion Safety Program.
Paul Ballantyne	Of Chalk River Laboratories (CRL); attachment to JET, Safety Engineer, Active Gas Handling Group.
Allan Rolfe	Of SPAR Aerospace; attachment to JET; Remote Handling Applications Group Leader.
Cliff Brown	Of Qualprotech; attachment to PPPL; Radiofrequency Engineer.
Clive Holloway	Of SPAR Aerospace; attachment to NET; research into reactor remote maintenance strategies.

PHOTO: ONTARIO HYDRO RESEARCH DIVISION

While ITER is expected—for short periods of time—to generate as much as 1,000 megawatts of fusion power as heat and radiation energy, it is not intended to produce electricity.

CFFTP is actively involved in ITER design and in research and development. CFFTP staff attached to the ITER program through the European team, assisted in several areas of the design concept, including safety systems, definition of siting requirements, integration of reactor systems, building and site layout, and the study of site power supply needs.

As the only ITER participant with direct utility involvement, Canada can offer a unique and valuable role to the project. Through its staff attachments and associates in Canada, CFFTP can bring considerable practical experience on the design of nuclear facilities to the ITER tasks.

Responding Globally

While ITER is one of the key fusion projects CFFTP is involved with, it is not the only one. More than 20 countries are currently active in pursuing and developing fusion technology—and CFFTP is working with many of them to advance fusion knowledge at significant world projects.

For example, through CFFTP, Canadian engineers and scientists are working team members at three of the world's leading fusion projects, in addition to ITER. These are:

- The Joint European Torus (JET) in England, which CFFTP has been associated with since 1984.
- The Next European Torus (NET), a next step fusion reactor project which is the European counterpart to ITER for advanced research and development; and
- The Tokamak Fusion Test Reactor (TFTR) at Princeton University in the United States, a large operational experimental fusion reactor. This reactor is scheduled to experiment with tritium-burning fusion plasmas in 1993.

International Links—Domestic Gains

It is through these international efforts that CFFTP works to promote Canadian industry and extend Canada's scientific capabilities.

Drawing on the expertise of staff in associate organizations and partners, CFFTP identifies opportunities for Canadian technology to respond to global fusion challenges.

In contributing to world fusion development through Canada's strategic knowledge of tritium technology, materials, robotics, nuclear safety, design and engineering, CFFTP is helping to secure a place for Canada in the energy world of tomorrow.

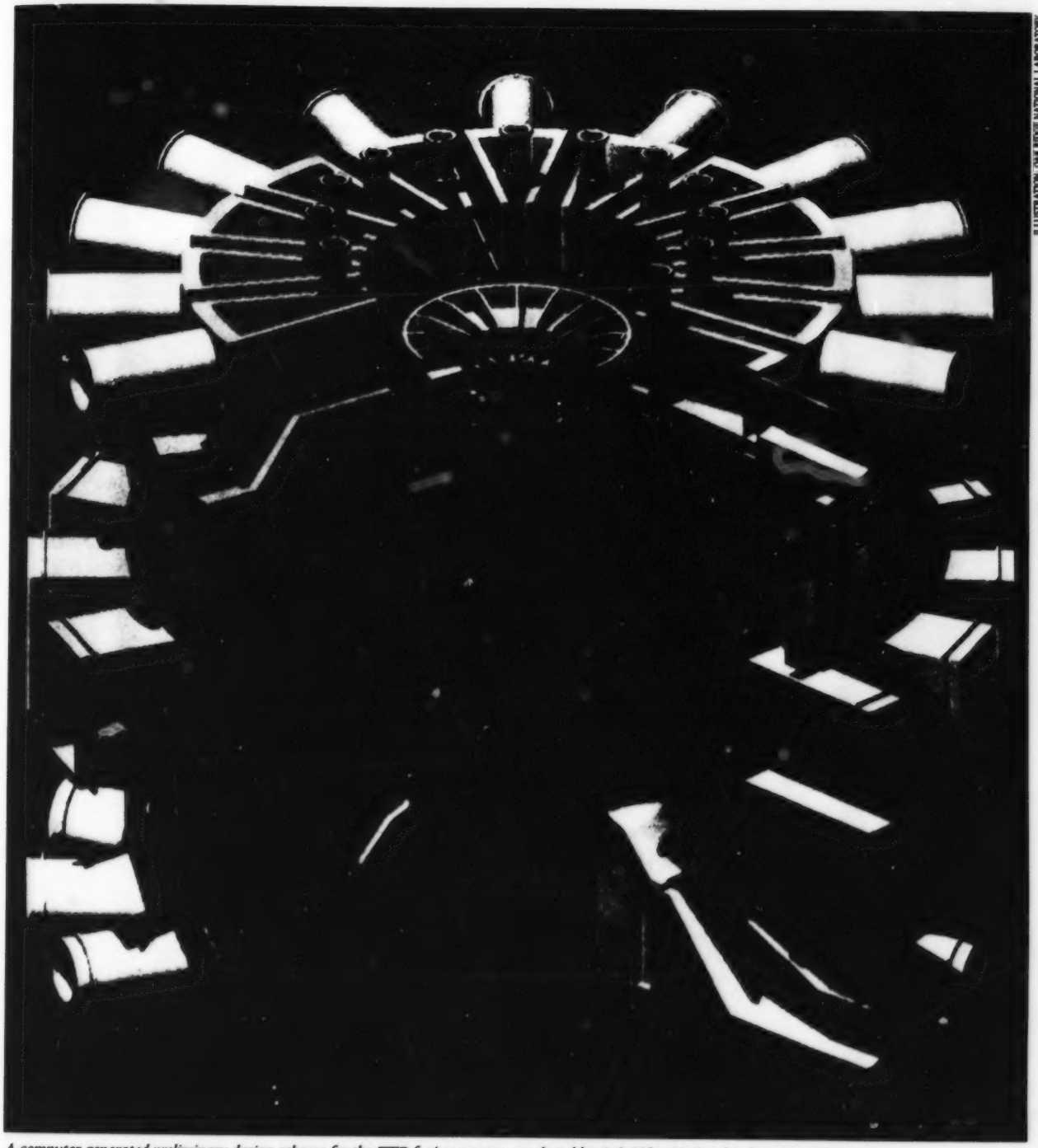


ILLUSTRATION: OAK RIDGE NATIONAL LABORATORY

A computer generated preliminary design scheme for the ITER fusion reactor--produced by Oak Ridge National Laboratory, USA.

Human Resource Development

Canada's ability to continue to participate in leading edge scientific research, in the global fusion program, and in competitive bidding for international technical contracts depends upon experienced and qualified people.

Canadian scientists, researchers, and technicians are essential for the Canadian Fusion Fuels Technology Project's (CFFTP) contribution. They are essential to Canada's fusion participation now; they are equally essential to any long-term domestic development of fusion energy in Canada.

CFFTP plays a critical and important role in developing Canadian human resources for fusion research. This requires working with universities and industries to identify, train, and provide entry level positions for Canada's young scientists and researchers. It also requires creating and maintaining career opportunities in the fusion field.

Working with Universities

CFFTP is working in partnership with universities to increase awareness of Canada's role in fusion research and development.

In doing so, CFFTP hopes to enlarge the pool of people who understand the basic concepts of fusion power, and who choose to enter graduate studies on fusion-related topics, or who join the private sector to advance fusion research.

CFFTP also makes effective use of summer students and co-operative program students in order to provide learning opportunities in fusion R & D.

Two key initiatives are underway to increase fusion interest at universities. These are the Fusion Student Award program and the Fusion Technology Fellowship program. Both are sponsored by CFFTP.

Student Award Program

The Fusion Student Award program is a new initiative which will recognize outstanding students involved directly or indirectly in fusion energy studies. Students who have demonstrated a high level of accomplishment will be eligible for the award.

Three awards will be granted annually; each with a value of $1,000. Two of these awards will be related to studies in the fusion field; the third will be granted for studies in science or engineering indirectly related to fusion.

Fusion Technology Fellowships

The Fusion Technology Fellowship program supports graduate studies and research in fusion technology for individuals pursuing a Masters or Doctorate degree program at universities in Canada or abroad. A stipend of up to $10,000 per year, plus tuition, is offered to successful candidates. The Fellowship is renewable annually subject to achievement.

This program seeks to unite university research with established fusion R & D projects through jointly sponsored research and assignments.

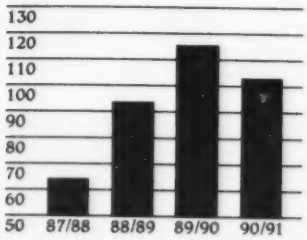
Potential sites for such assignments, which would span three to four months, include Atomic Energy of Canada's Chalk River Laboratories, Ontario Hydro's Research Division, Centre canadien de fusion magnétique, selected industries, national laboratories, universities at home and abroad, and foreign fusion projects.

Partnership with Industry

To assist Canadian companies in obtaining international contracts, CFFTP needs to ensure a level of expertise within industry that is competitive and can be applied strategically.

To help maintain and create career opportunities, CFFTP works with industry to develop entry level positions related to fusion research. It also encourages international attachments—spanning from a few weeks to several years—for both its own staff and subcontractors' staff.

Estimated Person Years of Skill Development
1987–1991



The estimated equivalent person years of skill development is based on expenditures of $110K per person in 1990/91.

Profile–Bill Morison

A pioneer of Canada's nuclear industry–W.G. (Bill) Morison retired from Ontario Hydro at the end of January 1991.

Respected and honoured for his dedication to engineering excellence, Bill spent more than 41 years with Ontario Hydro–the last eight as Vice-President of Hydro's internationally-renown Design and Construction Branch.

In this position, he also oversaw Hydro's participation in and contribution to fusion research, and was a member of the Canadian Fusion Fuels Technology Project's (CFFTP) Steering Committee.

Through his long career with Ontario Hydro, which included a 12-year attachment to Atomic Energy of Canada Limited, Bill worked on a broad range of projects involving innovative developments in the energy field.

Bill's significant research and knowledge was instrumental to the early development of nuclear power in Canada. As chief design engineer of Canada's first commercial nuclear power station–Pickering nuclear generating station–Bill also was responsible for several design innovations related to safety, heavy water containment, maintenance, and

PHOTO: ONTARIO HYDRO

Bill Morison (left) founder of CFFTP with Don Dautovich, Program Manager, CFFTP.

construction practices. Notable among these was the introduction of a vacuum containment system.

Bill's career coincided with the growth of nuclear technology within Canada. His solutions to engineering problems have been well documented in about 90 papers, reports, and publications.

While he has retired from Hydro, Bill has not retired from contributing to Canada's future energy challenges. He has established his own business, and will be assisting CFFTP in future on fusion research and development.

Profile–Fellowship Student

The Canadian Fusion Fuels Technology Project's (CFFTP) first fellowship student is 23-year-old Michael A. Graf.

While obtaining a Bachelor of Science degree from the University of Toronto's Engineering Science program, Michael specialized in nuclear and thermal power studies.

He is now in the Department of Nuclear Engineering at the Massachusetts Institute of Technology (MIT) studying toward a Doctorate degree.

While at MIT, Michael is responsible for the laser impurity injector project which will be capable of introducing controlled amounts of impurity atoms into the plasma for use in making both local edge plasma measurements as well as global particle confinement time measurements. Michael will also be working on the

PHOTO: M. GRAF

Michael Graf, CFFTP's First Fellowship Student specializes in nuclear and thermal power studies at Massachusetts Institute of Technology.

development of a spectrometer to be used for impurity line radiation analysis.

Michael is interested in the engineering aspects of fusion technology–a challenging field with problems that must be addressed if practical fusion energy is to become a reality.

The CFFTP Organization

CFFTP Steering Committee Members and Participants

*Official Members

Dr. J. David Tyrer *(Observer)*
Premier's Council Technology Fund
Toronto, Ontario

Dr. Gerald Dolling*
AECL/Chalk River Laboratories
Chalk River, Ontario

Dr. D.F. Torgerson*
AECL/Chalk River Laboratories
Chalk River, Ontario

Dr. G.J. Phillips
AECL/Chalk River Laboratories
Chalk River, Ontario

Dr. D.P. Jackson
AECL/Chalk River Laboratories
Chalk River, Ontario

Mr. Paul Bakker*
Ministry of Energy
Toronto, Ontario

Mr. H.S. Irvine*
Ontario Hydro
Toronto, Ontario

Dr. R. Higgin
Ontario Energy Board
Toronto, Ontario

Dr. Ralph Green* *(Retired)*
AECL/Chalk River Laboratories
Chalk River, Ontario

PHOTO ONTARIO HYDRO

Steering Committee Members: Left to right–Paul Bakker, Dave Torgerson, Hugh Irvine, Gerald Dolling.

Technical Advisory Committee

Dr. J.L. Anderson
Los Alamos National Laboratory
Los Alamos, New Mexico

Dr. R. Morrison
Energy, Mines and Resources
Ottawa, Ontario

Prof. A. Harms
McMaster University
Hamilton, Ontario

Dr. Y. Naruse
Japan Atomic Energy
Research Institute
Japan

Dr. J. Darvas
Commission of the
European Communities
Bruxelles, Belgium

Dr. Richard A. Bolton
Centre Canadian de fusion magnétique
Varennes, Quebec

Dr. G.J. Phillips
AECL/Chalk River Laboratories
Chalk River, Ontario

Industrial Advisory Committee

Mr. Alex Robertson
Canatom (Ontario) Inc.
Toronto, Ontario

Mr. H. Martin
Martin, McCubbin & Associates Ltd.
Mississauga, Ontario

Mr. C.R. Tyner
Nova Magnetics Limited
Dartmouth, Nova Scotia

Mr. P. Stefow
SPAR Aerospace Limited
Weston, Ontario

Mr. E. Card
Wardrop Engineering Consultants
Mississauga, Ontario

Mr. N. Aspin
Electrical and Electronic
Manufacturers Association
of Canada
Rexdale, Ontario

Mr. E.S. Fox
E.S. Fox Limited
Welland, Ontario

Mr. J. Richman
Spectrum Engineering Corporation
Peterborough, Ontario

Mr. D.A. Scott
Atomic Energy of Canada Limited
Mississauga, Ontario

Mr. F. Stern
Stern Laboratories
Hamilton, Ontario

Dr. G.J. Phillips
AECL/Chalk River Laboratories
Chalk River, Ontario

Mr. C.C. Adamson
N.E.L. Engineering
Peterborough, Ontario

Mr. John W. Speirs
AECL/Chalk River Laboratories
Chalk River, Ontario

Mr. James C. Smith
Babcock & Wilcox Canada
North York, Ontario

Dr. K. Torr
EG&G Labserco
Oakville, Ontario

Mr. Grant Unsworth
Monserco Limited
Mississauga, Ontario

Mr. J. Robinson
Qualprotech Inc.
Oakville, Ontario

CFFTP Staff

1. Hank Brunnader, 2. Sandy Howland,
3. Nick Markettos, 4. Anita Mah, 5. Ann Palen,
6. Sonja Morgan, 7. John Blevins, 8. Ron Matsugu,
9. Bev Andrews, 10. Carol Boose, 11. Dorothy Slocum,
12. Peter Ladd, 13. Mark Wright, 14. Lorraine Causey,
15. Hilda Maurer, 16. Martin Carney,
17. Maryann Zito, 18. Kam Wong, 19. Eva Tsalkizis,
20. Don Dautovich, 21. Pat Bailey,
22. Ahmad Arjomandi, 23. Rob French,
24. Allan Meikle, 25. Woytiech Fundamenski,
26. Jeff Stringer, 27. Paul Gierszewski,
28. Brendan Yeung, 29. Gary Vivian, 30. Otto Kveton,
31. Joe Lehman, 32. Marcelino Cruz

Absent from photo:

Janine Loring, Elizabeth Morris, Ed Fenton,
Tony Natalizio, John Robinson, Barry Wallace.

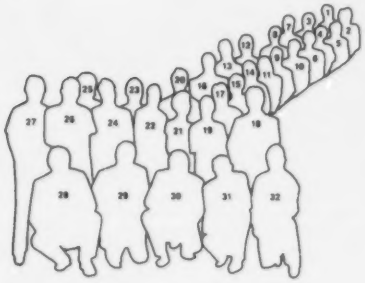


PHOTO: ONTARIO HYDRO

Organization Chart

Financial Report

Management's Responsibility for the Financial Report

The accompanying financial statements of CFFTP are the responsibility of the management of the Project. They have been prepared in accordance with the requirements laid down in the Second Term Agreement between Ontario Hydro and Atomic Energy of Canada Limited, and between Ontario Hydro and the Ontario Ministry of Industry, Trade and Technology. All costs incurred in the year have been accurately recorded in the accounts as they apply to particular projects, or allocated to all projects in a systematic and rational manner. We are satisfied that the financial statements have been properly prepared within reasonable limits of materiality.

The operations of CFFTP are controlled by the Ontario Hydro Management System. As members of management of the Project, we believe that the Project and Ontario Hydro have systems of internal control adequate to permit the preparation of accurate statements in accordance with generally accepted accounting principles and those specified in the Second Term Agreement.

The financial statements have been examined by Ernst & Young, independent external auditors, in order to ensure that the statements present fairly the costs of the Project. The scope of their examination and opinion are outlined in the auditor's report.

D.P. Dautovich
Program Manager

B.C. Yeung
Manager, Finance and Operations

Auditors' Report

To Atomic Energy of Canada Limited, the Ministry of Industry, Trade and Technology (Province of Ontario) and Ontario Hydro

We have audited the statements of net project expenditures, accumulated net expenditures and contributions by participants and changes in financial resources of *The Canadian Fusion Fuels Technology Project* (Second Term Agreements) for the year ended March 31, 1991. These financial statements are the responsibility of the Project's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with generally accepted auditing standards. Those standards require that we plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

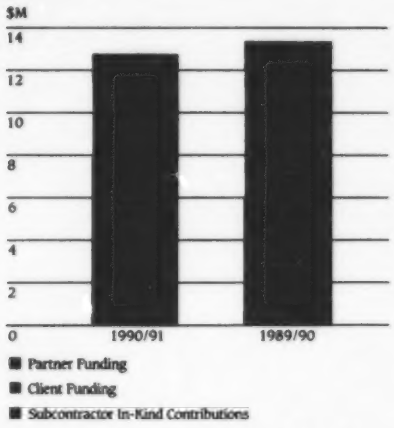
In our opinion, these financial statements present fairly, in all material respects, the net expenditures of the Project, accumulated net expenditures and contributions by participants and changes in financial resources for the year ended March 31, 1991 in accordance with the provisions of the Second Term Agreements of *The Canadian Fusion Fuels Technology Project* and significant interpretations thereof as described in the notes to the financial statements.

Toronto, Canada,
May 24, 1991.

Ernst & Young
Chartered Accountants

The Canadian Fusion Fuels Technology Project
[Second Term Agreements]
March 31, 1991

Source of Funds

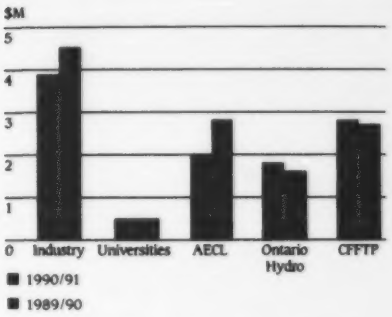


The total source of funds, which includes the sum of partner funding, client funding, and subcontractor in-kind contributions for the fiscal year 1990/91 reached $12.9 million, down from $13.4 million in 1989/90.

The 1990/91 partner funding for the Project's net expenditures was $7.9 million, an increase of $1.9 million over last year representing increased support from the Federal Government. The increase in partner funding offsets part of the decrease in client funding in fusion programs overseas. Total client funding for 1990/91 amounted to $3.7 million, of which $1.2 million flowed directly to associated companies without passing through CFFTP accounts. These contracts were developed with the help of CFFTP representation and assistance.

The 1990/91 subcontractor in-kind contribution was $1.3 million. These contributions are provided on specific contracts, usually in the form of discounted billing, uncharged time or costs related to the contracts. Subcontractor in-kind contributions are an indicator of subcontractor interest in and support for the Project's technical activities.

Distribution by Sector



CFFTP works in conjunction with several Canadian resource sectors. The distribution of partner and total client funds by sector shows contract and related expenditures which totalled $11.0 million in 1990/91. Subcontractor in-kind contributions are not included since they are contributed by the subcontractors themselves, and as such, do not represent an inflow to them.

Statement of Net Project Expenditures

Year ended March 31

	1991 $	1990 $
REVENUE		
Partners' contributions	**7,924,982**	6,627,386
Client funding* *(note 2(b))*		
fusion projects	**1,217,158**	1,497,033
business opportunities	**1,259,065**	2,423,054
Royalties	**10,177**	4,400
	2,486,400	3,924,487
	10,411,382	10,551,873
EXPENDITURES *(note 2(c))*		
Technical Contracts		
Fusion systems and engineering		
Blanket and first wall systems	**1,391,565**	1,334,346
Fusion fuels systems	**1,953,013**	1,631,495
Alternate concepts	**66,269**	54,783
Facility engineering and safety services		
Safety and environment	**592,634**	682,250
Facility systems	**537,114**	349,540
Layout and maintenance	**688,572**	688,279
Technology applications		
Services	**717,185**	895,459
Business opportunities	**1,143,729**	1,572,954
Technology transfer and planning	**83,695**	–
	7,173,776	7,209,106
Project management and administration		
Technical and management salaries	**1,637,179**	1,353,900
Project support, site and services	**737,441**	831,900
Publications and communications	**132,395**	125,400
Travel, general and audit expenses	**292,820**	279,077
	2,799,835	2,590,277
	9,973,611	9,799,383
RESERVE FUND *(note 5)*	**390,800**	117,000
Excess of revenue over expenditures and reserve fund for the year	**46,971**	635,490

* *Client funding in this statement does not include client funds that flowed directly into associated companies, and subcontractor-in-kind contributions* (notes 2(f) and (g)). *In 1991, the amounts reported to us were $1.2 million (1990–$2.2 million (unaudited)) and $1.3 million (1990–$1.3 million) respectively. Total value of work performed for 1991, including expenditures for the year and these amounts, was $12.9 million (1990–$13.4 million (unaudited)).*

See accompanying notes

The Canadian Fusion Fuels Technology Project
[Second Term Agreements]
March 31, 1991

Statement of Accumulated Net Expenditures and Contributions by Participants

Year ended March 31

	Net expenditures $	Contributions $	Net excess expenditures/ (contributions) $
Accumulated as at March 31, 1990			
Atomic Energy of Canada Limited	6,529,285	6,680,000	(150,715)
Province of Ontario	3,421,649	3,558,186	(136,537)
Ontario Hydro	6,529,285	6,680,000	(150,715)
Total	**16,480,219**	**16,918,186**	**(437,967)**
Current year amounts			
Atomic Energy of Canada Limited	3,449,060	3,612,500	(163,440)
Province of Ontario	2,214,475	1,999,982	214,493
Ontario Hydro	2,214,476	2,312,500	(98,024)
Total	**7,878,011**	**7,924,982**	**(46,971)**
Accumulated as at March 31, 1991			
Atomic Energy of Canada Limited	9,978,345	10,292,500	(314,155)
Province of Ontario	5,636,124	5,558,168	77,956
Ontario Hydro	8,743,761	8,992,500	(248,739)
Total	**24,358,230**	**24,843,168**	**(484,938)**

See accompanying notes

Statement of Changes in Financial Resources

Year ended March 31

	1991 $	1990 $
FINANCIAL RESOURCES PROVIDED BY (USED IN)		
Fusion Research & Development Activities		
Sources		
Partners' contributions	**7,924,982**	6,627,386
Client funding–fusion projects	**1,217,158**	1,497,033
Uses		
Technical contracts expenditures–fusion	**(6,030,047)**	(5,636,152)
Project management and administration	**(2,799,835)**	(2,590,277)
Increase (decrease) in financial resources during the year	**312,258**	(102,010)
Business Opportunities Activities		
Sources		
Client funding–business opportunities	**1,259,065**	2,423,054
Royalties	**10,177**	4,400
Uses		
Technical contracts expenditures	**(1,143,729)**	(1,572,954)
Increase in financial resources during the year	**125,513**	854,500
Reserve Fund expenditures	**(6,975)**	–
Financial resources, beginning of year	**554,967**	(197,523)
Financial resources, end of year	**985,763**	554,967
FINANCIAL RESOURCES ARE COMPRISED OF		
Receivable from (payable to) Ontario Hydro to cover over (under) contributions from partners		
Atomic Energy of Canada Limited	**314,155**	150,715
Province of Ontario	**(77,956)**	136,537
Ontario Hydro	**248,739**	150,715
	484,938	437,967
Reserve Fund	**500,825**	117,000
Total	**985,763**	554,967

See accompanying notes

1. Purpose of the Project

The Canadian Fusion Fuels Technology Project (the "Project") was formed under a Comprehensive Agreement in 1983 (the "First Term Agreement") to develop expertise in tritium-related technology and robotics for the development of fusion powered systems. The First Term Agreement terminated on March 31, 1987. A Second Term Agreement which covers the period from April 1, 1987 to March 31, 1992 was signed during 1987 by Ontario Hydro and Atomic Energy of Canada Limited ("AECL") (each of which agreed to fund 50% of the net project expenditures for this period).

During 1989, the Province of Ontario (represented by the Ministry of Industry, Trade and Technology) and Ontario Hydro signed an additional Second Term Agreement which covers the period from September 1, 1988 to March 31, 1993. The agreement reflects a commitment by the Province of Ontario to match the contributions of the other partners up to a prescribed limit of $9.4 million.

Ontario Hydro is committed to provide the Project with $11 million under the Second Term Agreement. AECL is committed to provide the Project with $11 million under the Second Term Agreement plus additional funding of $3.5 million for the period from September 1, 1990 to March 31, 1992 from the Department of Energy, Mines and Resources through the Panel on Energy Research and Development.

The net effect of the two Second Term agreements is that beginning September 1, 1990 AECL began funding 50% of the net project expenditures while Ontario Hydro and the Province of Ontario began funding 25% each.

Ontario Hydro is responsible for the management of the Project and, in this regard, is authorized to enter into agreements with outside parties to provide the necessary engineering and administrative services to fulfill the mandate of the Project.

2. Significant Accounting Policies

The following significant accounting policies have been approved by the Project's Steering Committee for purposes of accounting for the Second Term Agreements:

(a) Contributions by partners are recorded by Ontario Hydro on behalf of the Project as they are due, according to the terms of the operating agreements.

(b) Client funding represents expenditure reimbursements and revenue. Reimbursements and revenue are recognized on the accrual basis at year end, where there is reasonable expectation of future receipt.

(c) Expenditures are recorded using the accrual basis of accounting at year end. Costs include shared branch and divisional expenses, following Ontario Hydro's standard accounting practices and procedures, with the exception of the application of the standard corporate overhead charge, which has been waived for this Project.

(d) Consistent with the Project's stated goal to provide benefits to its participants in the short-term and to elevate Canada's overall level of technology, fusion-related business opportunities are actively pursued in order to expand the volume of work available to participants and generate additional revenue. Thus a reserve fund has been established to record the excess of revenue over expenditures from related business contracts.

(e) Any interest earned on funds advanced by the partners to Ontario Hydro in excess of net Project expenditures is not credited to the Project, nor is interest charged on funds provided by Ontario Hydro for expenditures in excess of advances.

(f) Client funding flowing directly to associated companies represents revenue received directly by associated companies as a result of CFFTP representation and assistance. These revenues are not included in CFFTP's income but represent an increase in value of work created by CFFTP.

(g) Subcontractor-in-kind contributions are provided by CFFTP subcontractors on specific contracts, usually in the form of discounted billings, uncharged time or costs related to the contracts. They are not included in CFFTP's income but represent an increase in value of work created by CFFTP.

3. Related Party Transactions

The project subcontracted certain work to both AECL and Ontario Hydro during the year as follows:

	1991 $	1990 $
Payments to AECL by CFFTP	**2,040,049**	2,109,697
Payments to AECL directly by fusion clients (1990–unaudited)	**7,800**	714,000
Total to AECL	**2,047,849**	2,823,697
Payments to Ontario Hydro by CFFTP	**1,828,234**	1,451,074
Payments to Ontario Hydro directly by fusion clients (1990–unaudited)	**–**	148,000
Total to Ontario Hydro	**1,828,234**	1,599,074

4. Payments to Industry and Universities

	1991 $	1990 $
Payments to Industry by CFFTP	**2,775,853**	3,136,714
Payments to Industry directly by fusion clients (1990–unaudited)	**1,147,000**	1,321,000
Total to Industry	**3,922,853**	4,457,714
Payments to Universities by CFFTP	**544,357**	544,207

5. Reserve Fund

A provision of $390,800, which approximates the excess of revenue over expenditures from related business contracts was added to the Reserve Fund in 1991. The closing balance of the Reserve Fund as at March 31, 1991 is $500,825.

6. Comparative Figures

Certain of the 1990 comparative figures have been reclassified to conform to the presentation adopted in the current year.

Communications

Fusion research, as undertaken by the Canadian Fusion Fuels Technology Project (CFFTP) offers important advantages in both the short and long term.

By working with industry and universities, CFFTP is helping to develop Canada's scientific capabilities today, and the exporting of Canadian goods and services abroad. Over the long term, fusion holds promise as an exciting energy option.

The mandate of CFFTP's Communications Program is to inform key audiences of these advantages, increase awareness of fusion research in general, and track CFFTP's achievements and benefits. These audiences include the Canadian and Ontario Governments, the international community, industry and the scientific community, and the general public.

Of particular importance is CFFTP's involvement and partnership with educational facilities.

In promoting fusion research as a future career alternative for students, CFFTP is working to ensure the availability of qualified human resources over the long term. It is also fostering an awareness among young Canadians of fusion power as a potential future energy option, which could address important environmental concerns.

Other areas of prime interest include disseminating information on technological advances in fusion energy, promoting industrial participation, and capitalizing on the benefits of fusion research.

Publications and communications media currently available from CFFTP include:

CFFTP Journal

A technical newsletter, published three times a year, the CFFTP Journal provides information on research and development directions, international liaisons, and CFFTP project initiatives.

CFFTP Annual Report

A yearly review of CFFTP activities, achievements, and financial results.

CFFTP Brochures

General Information
Provides overview of CFFTP.

Services & Products
Provides detail on services and products offered by CFFTP and clients.

Laboratory Capabilities
Provides information on laboratories associated with CFFTP.

Product Bulletins
Specification sheets on products co-funded by CFFTP.

CFFTP Technical Reports and Conference Papers
Reports on CFFTP research and development projects, and papers delivered by CFFTP staff and associates at fusion and nuclear conferences–this material is intended for scientists and engineers working in fusion and fusion-related fields and technologies. A complete listing is found on page 33.

CFFTP Video

"A Canadian Fusion Energy Initiative"
An overview of CFFTP's involvement in fusion research and its associations with industrial and scientific communities.

CFFTP Technical Reports and Conference Papers

Alternate Fusion Concepts: Status & Plans
P. Gierszewski, A.A. Harms, S.B. Nickerson. October 1990. **9009**

Tritium Behaviour in Ceramic Breeder Blankets
[Paper presented at the International School of Plasma Physics, Piero Caldiorola, Varenna 6–15 Sept 1989; CEC paper no. 12540 EN; AECL paper no. 10042]. J. Miller, G. Bonizzoni & E. Sindoni, eds. May 1990. **9010**

Alternative Confinement System for NET/ITER Blanket Handling: Final Report
March 1990. **9012**

Deuterium Permeation & Diffusion in High Purity Beryllium
[Preprint of paper Jr. of Nucl. Materials, 175 (1990) 90–95]. E. Abramov, M.P. Riehm, D.A. Thompson, W.W. Smeltzer. May 1990. **9013**

ITER Fuel Cycle Systems Layout Conceptual Design. Rev. 2.0
[ITER document no. ITER-IL-FC-2.4-0-8] O. Kveton, C. Barness, H. Brunnader, P. Dinner, A. Epifanov, et al October 1990. **9015**

Flux & Fluence Dependence of H + Trapping in Graphite
[Preprint of paper Jr. Nucl. Materials, 176 & 177 (1990) 992–999]. J.W. Davis, A.A. Haasz, D.S. Walsh November 1990. **9022**

Nuclear Technology
[Nuclear Fusion, 30, 9 (1990) 1905–1917]. G.E. Shatalov, M. Abdou, P.J. Dinner, H. Iida. November 1990. **9023**

Magnetic Confinement. Section 3: The Vacuum System
[Nuclear Fusion 30, 9 (1990) 1817–1862]. P. Komarek, C.C. Baker, G.O. Filatov, S. Shimamoto, P. Dinner. November 1990. **9024**

ITER Isotope Separation System Conceptual Design Description: ALSB Case. Rev. 1.0
[ITER document no. IL-FC-0.1-0-32]. A. Busigin, S.K. Sood, O.K. Kveton, R.H. Sherman, J.L. Anderson, L.J. Wittenberg. July 1990. **9026**

ITER Isotope Separation System Conceptual Design Description. Rev. 2.0
[ITER document no. IL-FC-9.2-0-18] A. Busigin, S.K. Sood, O.K. Kveton, R.H. Sherman, J.L. Anderson. June 1990. **9027**

ITER Isotope Separation System Alternative Distributed ISS Design Study. Rev. 0.
[ITER document no. IL-FC-9.2-0-31]. A. Busigin, S.K. Sood, O.K. Kveton, R.H. Sherman, J.L. Anderson. September 1990. **9028**

ITER Fuel Cleanup System Conceptual Design Description
[ITER document no. IL-FC-7.1-0-7]. R.S. Willms, A. Busigin, S.K. Sood, K.M. Kalyanam, B. Dean. August 1990. **9029**

Fuel Cycle R&D For ITER: A summary of Objectives & Current Status
[Fusion Eng & Design 12 [1990] 287–291]. P.J. Dinner. January 1990. **9033**

Study of Erosion & H-Recycle/Inventory of Carbon/Graphite
A.A. Haasz, J.W. Davis. April 1990. **9034**

Search for Neutron Emission Induced by Thermal Cycling of Metal Deuterides
[Paper submitted to Il Nuovo Cimento, Italian Physical Society, September 1989]. N.P. Kherani, W.T. Shmayda, A.B. Antoniazzi. April 1990. **9036**

Chemically Enhanced Self-Sputtering of Carbon
[Preprint of paper intended for publication in a journal or proceeding; Appl. Phys. Lett. 57 (19) 5 Nov 1990, pp. 1976–1977]. J.W. Davis, A.A. Haasz. May 1990. **9037**

Erosion & Hydrogen Retention of Graphite for First Wall Use in Fusion Reactors
A.A. Haasz, J.W. Davis. June 1990. **9040**

Impurity Transport at the Plasma Edge

[Invited paper to 9th Int. Conf. on Plasma Survace Interactions in Controlled Fusion Devices, 20-25 May, 1990, Bournemouth, U.K.; Jr. of Nucl. Materials 176 & 177 (1990) 51-64]. P.C. Stangeby. June 1990. **9041**

Magnitude & Direction of Forces on Impurities Near a Divertor Plate. An Exploratory Investigation

[Invited paper to the Satellite Workshop of the 9th Intl. Conf. on Plasma Surface Interactions 'Relevance, Radiation & Stability of a Cold Layer at the Plasma Edge for Fusion Reactors' 28-30 May 1990, Cadarache, France]. P.C. Stangeby. June 1990. **9042**

Chemical Erosion of Sintered Boron Carbide Due to H + Impact

[Reprint of paper Jr. of Nucl. Materials, 175 (1990) 117-120]. J.W. Davis, A.A. Haasz. June 1990. **9043**

Corrosion of Carbon Steel in Aqueous Lithium Hydroxide Under a Hydrogen Blanket

[Preprint of a paper submitted to Corrosion; Corrosion: 46, 12 (1990) 1002-1006]. J.W. Graydon, D.W. Kirk. March 1990. **9045**

Corrosion of Nickel & Stainless Steels in Concentrated Lithium Hydroxide Solutions

[Preprint of a paper submitted to Corrosion; Corrosion. 46, 12 (1990) 1021-1028]. J.W. Graydon, D.W. Kirk. June 1990. **9046**

Fusion Solid-Breeder Radiation Experience at CRNL

[AECL report no. AECL 10228; paper submitted to CNA meeting June 1990]. R.A. Verrall, J.M. Miller. June 1990. **9048**

Thermal Desorption of Deuterium from Polycrystalline Nickel Pre-Implanted with Helium

[Paper presented for publication Jr. of Nucl. Materials, 182 (1991)]. S. Shi, E. Abramov, D.A. Thompson, W.W. Smeltzer. July 1990. **9051**

Radiolysis of the Aqueous Lithium Salt Blanket

[AECL paper no. 10269; Presented at Canadian Nuclear Society Conference, Toronto, June 1990] A.J. Elliot, M.V. Chenier. December 1990. **9054**

Comparison of Rigid Versus Flexible Confinement Systems for NET/ITER Blanket Handling: Final Report

[Wardrop report no. 90-8004-04-00] J. Stringer. August 1990. **9055**

Synergistic Effects Between Helium & Deuterium on Gas Detrapping in Polycrystalline Nickel

[Paper submitted to the Journal of Nuclear Materials] E. Abramov, S. Shi, D.A. Thompson, W.W. Smeltzer. September 1990. **9057**

Subsonic & Supersonic Divertor Solutions

[Reprint of paper submitted to Plasma Phys & Controlled Fusion] P.C. Stangeby. October 1990. **9060**

ITER: TVPS Remote Handling Critical Design Issues: Final

[Wardrop report no. 90-8004-05-00] J. Stringer. September 1990. **9061**

In-Situ Tritium Recovery From Li20 Irradiated in Fast Neutron Flux – BEATRIX-II Initial Results

[Reprint of paper presented at the 4th Topical Meeting on Technology of Fusion Energy, Oak Brook, IL, Oct 7-11, 1990] T. Kurasawa, O.D. Slagle, G.W. Hollenberg, R.A. Verrall. October 1990. **9065**

ITER Hydrogen Isotope Separation System Conceptual Design Description

[Fusion Eng & Design 13 (1990) 77-89] A. Busigin, S.K. Sood, O.K. Kveton, P.J. Dinner, D.K. Murdoch, D. Leger. November 1990. **9074**

Tritium Recovery From Lithium Zirconate Spheres

[Presented at the 9th Topical Meeting on the Technology of Fusion Energy, Oakbrook, Ill, October 1990] J.M. Miller, S.R. Bokwa, D.S. MacDonald, R.A. Verrall. October 1990. **9078**

Measurement of the Thermal Properties of Electrically Conducting Liquids by the Anodic-Coated Transient Hot-Wire Technique

[Paper presented at the 12th European Conf. on Thermophysical Properties, Vienna, Austria, Sept. 24–28, 1990] G. Wang, R.C. Prasad, J.E.S. Venart. September 1990. **9079**

Energy Research in the 90's for Long Term Supply Options

[Notes from a presentation to the 4th McMaster University Nuclear Science & Engineering Symposium, October 1990, McMaster University, Hamilton] N.D. Markettos. October 1990. **9081**

In-Vessel Vehicle System For Remote Maintenance of Torus Interior

[Preprint of paper presented at the 16th SOFT Conference 1990] H. Jones, M. Heim. December 1990. **9085**

ITER Fuel Cycle Systems Cost Estimation Review. Rev. 1.0

[ITER document no. ITER-IL-FC-2.9-0-7b] O.K. Kveton. November 1990. **9091**

ITER Fuel Cycle Systems Energy Requirements. Rev. 0.0

[ITER document no. ITER-IL-FC-9.5.1-0-47] O.K. Kveton. November 1990. **9092**

Some Possibilities For Measuring Local Plasma Parameters in the Edge Plasma by Impurity Injection

[Preprint of a Letter to the Editor] P.C. Stangeby, J.D. Elder. December 1990. **9094**

Power Balance during Carbon Blooms in TFTR Discharges

[Paper submitted to the Satellite Workshop of the 9th Intl Conf on Plasma Surface Interactions, Centre D'Etudes Nucleaires de Cadarche Groupe de Recherche de l'Association Euratom-CEA sur la Fusion, May 1990, Castle of Cadarache, France] C.S. Pitcher, C.E. Bush, S.J. Kilpatrick, D.M. Manos, S.S. Medley, A.T. Ramsey, J. Schivell and M. Ulrickson. May 1990. **9099**

Power & Particle Balance During Neutral Beam Injection in TFTR

[Paper submitted to the 9th Intl Conf on Plasma Surface Interactions in Fusion Devices, Bournemouth International Centre, U.K.] C.S. Pitcher, R.V. Budny, K.W. Hill, S.J. Kilpatrick, D.M. Manos, S.S. Medley, A.T. Ramsey. July 1990. **90100**

Remote Maintenance of NET Torus Vacuum Pumping System

[Preprint of a paper intended for publication in a journal or proceedings] October 1990. C. Holloway, J. Stringer. **G-9062.**

Remote Maintenance of NET Cryogenic Pipe Connectors

[Preprint of a paper intended for publication in a journal or proceedings] October 1990. Ch. Barnes, L. Gumb, C. Holloway, H. Katheder, M. Selig, D. Stern, E. Villata. **G-9063.**

Assembly of the NET Machine

[Preprint of a paper intended for publication in a journal or proceedings] October 1990. F. Casci, C. Holloway, D. Maisonnier, G. Malavasi, E. Salpietro, E. Villata, G. Ghia, F. Olezza. **G-9064.**

Key Processes & Input Parameters for Environmental Tritium Models

[Preprint of paper presented at the 16th SOFT Conference, September 1990] September 1990. C. Bunnenberg, M. Taschner, G.L. Ogram. **G-9080.**

Dosimetry of Skin-Contact Exposure to Tritium Gas Contaminated Surfaces

December 1990. M. Legare. **G-9098.**

Field Evaluation of Passive HTO-in-Air Samplers at Chalk River Laboratories

[AECL report no. AECL-10358] March 1991. M.J. Wood. **G-9117.**

CFFTP Technical Reports and Conference Papers

CFFTP Presentations

Gierszewski, P.J.
U. Toronto Engineering Science Option Talk, Presentation on Fusion/CFFTP, 02/28/91

Blevins, J.
Fusion Basics Seminar, Presentation on Facilities Layout, 11/27/90

Gierszewski, P.J.
Fusion Basics Seminar, Presentation on Fusion First Wall and Blanket, 11/27/90

Stasko, R.
University of Toronto, Presentation on Fundamentals of Fusion, 09/25/90

Gierszewski, P.J.
St. Dunsten's Elementary School, Presentation to Grade 6-8 Students on Fusion, 03/05/91

Brunnader, H.
Fusion Basics Seminar, Presentation on Containment for Fusion Reactors, 11/27/90

Dautovich, D.P.
Presentation to Ortech on Fusion Energy Development, 05/18/90

Dautovich, D.P.
Energy, Mines and Resources, Presentation on 1989/90 Fusion Program Highlights, 05/31/90

Dautovich, D.P.
CFFTP, Presentation to P. Eggleton, W. Davidson, S&T Counsellors–Brussels and Bonn, 07/12/90

Brunnader, H.
CFFTP Safety Workshop, Presentation on ITER Safety Design Issues, 03/21/91

Vivian, G.A.
Safety and Environment Committee–Canadian Nuclear Association, Presentation on Fusion Energy in Canada: Business, Technology and Safety, 06/19/90

Robinson, J.
1990 CNA/CNS Conference, Presentation on The Industrial Benefits of Fusion, 06/06/90

Dautovich, D.P.
Fusion Briefing–CFFTP, Presentation to T. Rummery, President, AECL-Research on Fusion Status, 08/20/90

Dautovich, D.P.
CFFTP, Presentation to Hungarian Power Trust on Fusion Energy Development, Benefits to Canada in Science, Technology and Business, 10/23/90

Natalizio, A.
CFFTP Safety Workshop, Presentation on CFFTP Fusion Safety Criteria Program, 03/21/91

Matsugu, R.S.
American Nuclear Society–Ninth Topical Meeting on the Technology of Fusion Energy, Presentation on Tritium Fill Station to Charge Microballoons for Fusion Experiments, 10/07/90

Markettos, N.D.
4th McMaster University Nuclear Science & Engineering Symposium, Presentation on Energy Research in the 90's for Long Term Supply Options, 10/01/90

Wong, K.Y.
4th McMaster University Nuclear Science & Engineering Symposium, Presentation on Nuclear Fusion Technology in Canada, 10/01/90

Brunnader, H.
5th All-Union Conference on Engineering Problems of Fusion Reactors, Soviet Union Fusion Program, Presentation on Radioactive Confinement Design in ITER, 10/09/90